State of California
Environmental Protection Agency

AIR RESOURCES BOARD

An Update to Summer Temperature and Relative Humidity Profiles for the EMFAC2007 On-road Emissions Model

June 28, 2006

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Executive Summary

California’s EMFAC emissions model is used to estimate emissions from on-road mobile sources that contribute to emissions inventories for planning purposes and for some modeling purposes. When estimating total emissions in a given area, emissions factors (i.e., emissions per unit of activity) are adjusted before they are applied to travel activity. These adjustments include corrections made when ambient temperatures and humidities differ from the conditions set for standardized emissions tests. Under this project, ARB staff analyzed data for temperature and humidity within each planning sub-region on days when ozone reached levels that challenge efforts to attain and maintain air quality standards for ozone. New diurnal profiles that represent these challenging conditions have been prepared for use in the EMFAC model.

For this task, ARB staff produced diurnal temperature and relative humidity profiles to represent conditions understood to contribute to ozone levels most likely to challenge attainment and maintenance of the federal 8-hour ozone standard. These profiles will replace the current “summer” season profiles in EMFAC, in order to improve emissions estimation and modeling, and support planning decisions that target appropriate emission reductions. In addition to the profiles representing the federal 8-hour ozone standard, profiles were developed to represent challenging meteorological conditions for the State’s 8-hour and 1-hour ozone standards. The additional profiles can be used with EMFAC on an ad hoc basis but will not be included at this time as options in EMFAC’s routine menus.

The new temperature and relative humidity profiles were developed for each county portion of each air basin using sampling and estimation methods described in this document. The profiles representing the federal 8-hour ozone standard have been installed in a new draft working version of the EMFAC model (version 2.22.8). Following modification of both temperature and relative humidity profiles, emissions of reactive organic gases (ROG), carbon monoxide (CO), and oxides of nitrogen (NOx) increased in all areas of the state. The changes vary by area and by calendar year, as shown below in Table ES-1.

Table ES-1. Changes in Emissions Resulting from Application of Revised (Federal 8-Hour Ozone Standard) Temperature and Relative Humidity Profiles in EMFAC Version 2.22.8, Tons per Day (%)

2002			
Area	ROG-All processes	CO-All processes	NOx-All processes
Statewide	59.22 (5.16%)	302.55 (2.94%)	37.69 (2.95%)
South Coast AB	6.89 (1.55%)	35.40 (0.92%)	15.43 (2.68%)
San Joaquin AB	9.66 (7.62%)	67.45 (6.04%)	12.02 (4.04%)
Sacramento AB	7.61 (7.47%)	54.79 (5.86%)	4.58 (2.74%)
San Diego AB	1.24 (1.41%)	5.01 (0.61%)	4.35 (3.50%)
San Francisco AB	15.29 (6.96%)	91.85 (4.50%)	4.10 (1.40%)
2020			
Area	ROG- All processes	CO-All processes	NOx- All processes
Statewide	31.91 (7.44%)	79.77 (2.90%)	11.24 (1.80%)
South Coast AB	3.50 (2.30%)	8.26 (0.90%)	4.20 (2.28%)
San Joaquin AB	5.43 (10.29%)	17.23 (5.37%)	3.44 (3.21%)
Sacramento AB	4.46 (10.60%)	14.66 (5.43%)	1.32 (2.32%)
San Diego AB	0.92 (2.53%)	1.18 (0.97%)	1.39 (3.00%)
San Francisco AB	7.99 (10.99%)	20.21 (4.05%)	1.07 (1.24%)

Background

Correction factors are used to adjust base emissions rates in the EMFAC model when conditions differ from the conditions set for standardized emissions tests. Sets of correction factors for ambient temperature and relative humidity are used to adjust exhaust (especially starts) and evaporative (i.e., diurnal, hot-soak, running loss and resting loss) emissions for non-standard conditions. County-specific hourly temperatures and relative humidities are used as input to the model to adjust emissions for ambient temperatures that vary from 75 degrees Fahrenheit, and for absolute humidities that vary from 75 grains of water per pound of dry air (gr/lb).

Temperature profiles included in EMFAC 2002 v.2.2 (Apr2003) were estimated using temperature data from California Irrigation Management Information System (CIMIS), California Department of Forestry (CDF) meteorological stations, National Weather Service (NWS) weather buoys, and National Climatic Data Center (NCDC). In order to produce monthly average profiles for each county, temperature data from the calendar years 1988 through 1992 were used. The data at each monitoring station were interpolated into grid cells and then weighted by zip code-specific vehicle registrations. County-specific profiles for 1-hour ozone episode days and 8-hour CO episode days were estimated with uniform analytical methods, using temperature data monitored on days when 1-hour ozone or 8-hour CO levels exceeded their respective federal standards.

The primary purpose of this task was to produce new diurnal profiles for temperature and relative humidity that represent conditions when ozone levels challenge attainment of the federal 8-hour ozone standard. New profiles were developed for each county portion of each air basin, using weighted averages of hourly temperatures and relative humidities on approximately 18 total days over 9 years. The new profiles will replace the current “summer” profiles in EMFAC.

The new profiles are further improved in the following ways:

- Use of more recent (1996-2004) meteorological data,
- Separation of profiles for the portions of the counties in each air basin,
- Weighting of gridded temperatures and relative humidities by gridded VMT, rather than vehicle registrations by zipcode, better represents the conditions experienced by on-road vehicles ,and
- Exclusion of data from the CIMIS system, which utilizes non-standard measurement heights and stations located in irrigated, often cooler areas.

In addition to the profiles representing the federal 8-hour ozone standard, to be included in EMFAC2007 as defaults, profiles have been developed to represent the state 8-hour and state 1-hour ozone standards. The steps used to develop the new profiles are described below.

Step 1:
Spatial Resolution and Planning Perspectives for New Temperature Profiles

A key objective of the EMFAC model is to support the air quality planning process with best available data on emissions from on-road mobile sources.` For that purpose, motor vehicle inventories are often developed for areas more distinct than the county level at which temperature and relative humidity profiles are currently applied in EMFAC. EMFAC already has the capability to store and apply profiles for the portions of counties specific to each air basin (e.g., Solano County portion of the Sacramento Valley Air Basin and the Solano County portion of the San Francisco Bay Area Air Basin). EMFAC currently includes 69 such areas, which are described as geographic area indexes (GAIs). Thus, temperature and relative humidity profiles will be assembled for these sub-areas for use in the current EMFAC update. A list of GAIs is provided in Appendix A.

Because the planning process is concerned with air pollution for specific nonattainment areas, inventories at the 69 geographic areas in EMFAC are sometimes insufficient. Several such cases are listed below:

a) A nonattainment area for the 8-hour federal ozone standard has been designated for the western portion of Nevada County.
b) The Eastern Kern ozone nonattainment area is not fully contiguous with the Kern County portion of Mojave Desert Air Basin.
c) The Western Mojave Desert nonattainment areas (both ozone and PM10) are more limited than the San Bernardino County portion of Mojave Desert Air Basin.
d) The Sacramento ozone nonattainment area includes a portion of south Sutter County.
e) The Sutter Buttes ozone nonattainment area is a very small portion of Sutter County affected by ozone transport aloft.

With the possible exception of Nevada County, it appears unlikely that spatial temperature variations within the geographic areas listed above would have significant emissions impact. Further examination of temperature readings from Nevada County sites will indicate whether ozone season differences between the lower-elevation western and high-elevation eastern portions of the county merit development of a profile specific to the Western Nevada County nonattainment area. For all other areas, area-specific profiles will be sufficient for SIP planning purposes. More highly resolved profiles within counties may be useful for other purposes (e.g., estimating emissions within a port district for community health analysis), and could be used as input to EMFAC through the model's scenario generator.

Temperatures and Transport. Air quality plans consider the impacts of pollution transported from upwind areas, also affected by temperature. Ambient temperatures in the Central Valley, for example, affect the amount of smogforming gases destined for areas in the Mountain Counties Air Basin. Even within geographic areas, temperature variations can be important to the transport of ozone precursors. Resolution of temperatures for subareas within geographic areas will not be part of this project, however, due to the substantial time and resources that would be required to accommodate such modifications in the EMFAC model and its graphical user interface. The ozone precursor planning inventories developed for downwind nonattainment areas will emphasize local conditions in those areas on days when local emissions are most likely to contribute to exceedances of ozone standards.

Alternative Scenarios. The EMFAC model contains annual, seasonal, and monthly diurnal profiles for temperature and relative humidity. The summer seasonal profile is used to help develop plans to attain ozone standards. Air quality plans that respond to the federal 8-hour ozone standard are due in 2007, and the importance and time urgency of those plans cause this project to focus on that standard. Temperature and relative humidity profiles developed for the federal 8-hour ozone standard will become the new summertime defaults for EMFAC. Profiles appropriate to other goals (e.g., the State ozone standards or the current summer defaults) may also be needed in future analyses, but will remain outside the model. A general update to the winter seasonal profiles is not considered a high priority, since California has already attained federal and state carbon monoxide standards. Additional consideration will be given to year-round updates of temperature and relative humidity profiles for the San Joaquin Valley Air Basin and the South Coast Air Basin in the near future.

Step 2:
Selection of "High" Ozone Days for the EMFAC Temperature and Relative Humidity Profiles Update

This step describes the general principles and specific criteria by which days were selected for use in constructing new temperature and relative humidity profiles for EMFAC.

A. General Principles for Selecting Days

Several principles were established prior to the selection of days to be used in constructing new temperature and relative humidity profiles. Specific criteria applied later were consistent with these principles. Accordingly, the new profiles:

- Focus on the federal 8-hour ozone standard, emphasizing conditions that challenge attainment and maintenance of the standard,
- Become new summertime default profiles in EMFAC,
- Represent more recent data for ozone and meteorology,
- Apply to county portions of air basins,
- Emphasize local conditions rather than pollutant transport conditions, and
- Include profiles that represent the state 8-hour and state 1-hour ozone standards [these will remain outside the official EMFAC model at this time].

New profiles focus on the federal 8-hour ozone standard. The new profiles were designed to support the development of effective plans for attaining and maintaining the Federal 8-hour ozone standard (H&SC 40910). Since attainment of air quality standards is largely determined by their corresponding design values, federal 8-hour ozone design values[1] provided the primary targets for selecting "high" ozone days. Temperature and relative humidity data from the selected days were used to construct the new profiles for the EMFAC model.

New profiles emphasize episode conditions that challenge attainment and maintenance standards. Days on which the basin maximum ozone concentrations are` close to the prevailing design value do not always present a challenge to attainment or maintenance of an ozone standard.

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[1] The term "design value" was popularized in recent decades. It is a value that summarizes measured air quality data in a way that determines whether air quality data satisfy a particular standard. Different standards have different ways of calculating their respective design values. For example, the design value for the Federal 8-hour ozone standard is the average of the 4th highest daily values measured in each of the last three years. When this design value does not exceed 0.084 ppm (the effective level set for the standard) at any site in a region, the region qualifies for "attainment" of the Federal 8-hour ozone standard.

Therefore, criteria were applied to promote the selection of days that would challenge attainment and maintenance of the federal 8-hour ozone standard.

New profiles use meteorological data from 1996 through 2004. The previous temperature and relative humidity profiles were based on data from 1988 through 1992. Since 1992, significant changes in emissions, including evaporative emissions, have occurred in some regions of the state. Some of these changes, such as the lower reactivity of organic emissions or the changes in the spatial distribution of emissions from on-road vehicles could alter the sensitivity of ozone formation to temperature and/or relative humidity. Therefore, data from nine recent years (1996-2004) have been used to identify high ozone days on which to base the new profiles. The introduction of California's Phase 2 Reformulated Gasoline early in 1996 is the main reason for choosing that year as the starting year. The ending year, 2004, was selected because more recent data were preliminary, incomplete, or very difficult to obtain at the time this work was done.

New profiles apply to each county portion of each air basin. The new profiles represent county portions of air basins. EMFAC already includes place-holders for these profiles, but only county-wide profiles have been developed until now. Although county portions of air basins have their own profiles, the days on which these are based are the same for all parts of a basin. This is done because ozone is a secondary pollutant that has strongly regional characteristics, and consequently designations of attainment and non-attainment are most often made on a basinwide basis (H&SC 39607(e)).

Meteorological data from the selected days were used to characterize temperatures and relative humidities within a basin. The information was then summarized separately for each county portion of the basin. (The methods used to determine the hourly profiles are presented in Step 3.)

New profiles emphasize local rather than transport conditions. The new temperature and relative humidity profiles help support the planning process by emphasizing the local temperature and humidity conditions that lead to high ozone from within-basin emissions (H&SC 40912). In some cases, these conditions are similar to the conditions that favor transport of large amounts of ozone and ozone-forming emissions into a basin. In other cases, however, conditions that favor transport differ from the conditions that local attainment plans need to address. Although staff cannot precisely distinguish days when ozone transport conditions are the major contributors to high ozone levels, the selection approach emphasizes the contribution of local emissions to locally measured ozone concentrations.

Additional profiles address the state ozone standards. As a part of this effort, staff has also prepared new profiles that address the state 1-hour and 8-hour ozone standards. For these profiles, California design values for the state 1-hour and 8-hour ozone standards were used to select "high ozone" days. At this time, profiles that address the state standards will not be integrated into the EMFAC model.

B. General Approach to Day Selection

The criteria presented in this section were applied to all air basins. Basin-specific variations are presented in the succeeding section.

- **Minimum percentage of Design Value**

This first criterion served to eliminate from further consideration the vast majority of days when ozone levels were far below the prevailing design values for federal or state standards. To pass this criterion, the basin maximum 8-hour or 1-hour ozone concentration was required to be at least 85% of the relevant design value after accounting for background ozone, which was assumed to be 40 ppb. The calculation procedure is illustrated by the two examples below:

Example 1: For a design value of 140 ppb, days with basinwide maximum ozone of 125 ppb or higher would qualify because (125-40)/(140-40) = 0.85 = 85%.

Example 2: For a design value of 100 ppb, days with basinwide maximum ozone of 91 ppb or more would qualify because (91-40)/(100-40) = (51/60) = 0.85 or 85%.

- **Emphasize Conditions that Challenge Attainment and maintenance of Standards, and**
- **Emphasize Local Conditions not Transport Conditions**

A single criterion served to promote both of the goals stated above. In practice, it eliminated from further consideration many days on which relatively high ozone levels only occurred in a very small portion of a basin. Data from those days were not used for the new profiles because they tend to represent conditions that favor transport, in contrast to ozone formation from local emissions.

Furthermore, the goal of attainment plans is to attain and maintain compliance with air quality standards. Days on which very few sites record relatively high ozone levels are not likely to pose a strong challenge when developing attainment plans that address local emissions. The scenarios that make it hard to maintain compliance are likely to involve a more widespread ozone problem involving relatively high ozone levels at multiple sites.

A minimum number of sites measuring relatively high ozone (ozone within 85% of the value at the high site within the basin on each selected day) was determined for each basin, where the minimum number depended on the total number of ozone monitors in the basin. For this calculation, a correction for "background" ozone was not needed, and a screening function[2] produced the following results. For basins with three or fewer sites, only the one high site was required. For basins with 4 to 16 sites, one additional site within 85% of the high site was required. For basins with 17 or more sites, two additional sites within 85% of the high site were required.

In certain circumstances, the number of sites required was increased, or an otherwise qualifying day was excluded. These circumstances are summarized in Table 2-1 and described at greater lengh in section C, which follows the table.

- **Restrict Days to the Main Ozone Season**

Days with relatively high ozone rarely occur in California outside the months of May through October. In most cases, days outside this season were not used even if they passed the preceding criteria because they tend to represent unusual spring or fall conditions that are not likely to challenge efforts to attain ozone standards.

In a small fraction of cases, however, days outside the May-October period were selected. These exceptions involved the North Central Coast (Monterey Bay) Air Basin and the Bay Area (San Francisco) Air Basin. These two air basins are strongly affected by cold marine air on many mid-summer days, while warmer days with high ozone often occur in the early spring and late fall.

Table 2-1 summarizes the general selection criteria above and the basin-specific variations presented in section C following the table.

[2] The screening function was $N^{1/3}$ (or, the cube-root of N) rounded to the nearest integer.

Table 2-1. Day Selection Criteria by Air Basin

Air Basin	Sites	Days that Passed Initial Criteria*	Min. Sites Involved** to Qualify a Date: If the High Site was:	Sites Needed	Number of Days Selected (range wrt DV***)
Great Basin Valleys	2	108	Death Valley Mammoth - Gateway	1 2	18 (98.8% -- 102.5%)
Lake County	1	91	Lakeport	1	18 (98.4% -- 101.6%)
Lake Tahoe	3	90	Sandy Way Echo Summit	1 2	18 (98.6% -- 104.0%)
Mountain Counties	15	128	Cool Otherwise	3 4	18 (98.1% -- 103.0%)
Mojave Desert	9	134	Hesperia Phelan Otherwise	2 2 3	18 (98.0% -- 102.3%)
North Coast	3	67	Healdsburg Airport Ukiah	1 2	18 (98.4% -- 103.3%)
North Central Coast	10	41	Pinnacles Hollister Otherwise	2 2 3	18 (96.5% -- 104.9%)
Northeast Plateau	1	185	Yreka	1	18 (98.5% -- 101.6%)
South Coast	28	92	Crestline Otherwise	3 4	18 (97.7% -- 103.1%)

* Initial criteria specified (1) minimum level for the daily max 8-hour ozone and (2) minimum number of sites with “relatively” high ozone.
** Basin-specific criteria were based on review of ozone distributions and high site frequencies
*** Ranges for daily maximum 8-hour ozone are shown as percent of prevailing design value as some design values changed from 1996 to 2004.

Table 2.1 (cont.)

Air Basin	Sites	Days that Passed Initial Criteria*	Min. Sites Involved** to Qualify a Date		Number of Days Selected (range wrt DV***)
			If the High Site was:	**Sites Needed**	
South Central Coast	33	59	Simi Valley Ojai Otherwise	3 3 4	18 (96.8% -- 104.3%)
San Diego	11	37	Alpine Escondido Otherwise	2 2 3	18 (94.9% -- 106.0%)
San Francisco Bay Area	23	73	All cases	3	18 (98.8% -- 107.0%)
San Joaquin Valley	26	289	Sequoia (far downwind) Otherwise	5 4	18 (99.1% -- 101.7%)
Salton Sea	8	91	Palm Springs Otherwise	2 3	18 (97.1% -- 104.0%)
Sacramento Valley	25	142	Folsom Auburn Redding Otherwise	3 3 6 4	18 (99.0% -- 103.0%)

* Initial criteria specified (1) minimum level for the daily max 8-hour ozone and (2) minimum number of sites with “relatively” high ozone.
** Basin-specific criteria were based on review of ozone distributions and high site frequencies.
*** Ranges for daily maximum 8-hour ozone are shown as percent of prevailing design value as some design values changed from 1996 to 2004.

C. Day Selection by Air Basin

In this section, the day selection process by air basin is presented in more detail. The purpose is to provide basin-specific considerations in addition to the general day selection approach described above.

Great Basin Valleys. Death Valley and Mammoth Gateway sites were the only two sites that measured ozone in the Great Basin Valleys (GBV) Air Basin. Each was the high site (i.e., the site measuring a high level of ozone) on some of the days that passed initial screening steps. Death Valley was the key site, however, and it was required to be within 85% of the daily basinwide maximum. Mammoth Gateway is an elevated site that is highly affected by aloft transport, so Mammoth alone was not sufficient to qualify a day for use.

A total of 108 days passed the initial screening with respect to (1) annual design values and (2) sufficient ozone at Death Valley. From the 108 days, all days on which the basinwide maximum exactly equaled the basinwide design value (for the associated year) were selected. A balanced number of days above and below the design value were then selected to make a total of 18 days.

Lake County. Lake County (LC) is its own air basin. In Lake County, only one site, Lakeport, measured ozone. When the Lakeport ozone data were screened with respect to the annual design values, 91 days passed the initial screening. From the 91 days, all days on which ozone exactly equaled the basinwide design value (for the associated year) were selected. A balanced number of days above and below the design value were then selected to make a total of 18 days.

Lake Tahoe. The Lake Tahoe (LT) Air Basin had only two sites – Sandy Way and Echo Summit – that measured ozone from 1996 to 2004. Each was the high site on some of the days that passed initial screening steps. Sandy Way, in the town of South Lake Tahoe, was the key site, and it was required to be within 85% of the daily basinwide maximum. Echo Summit is an elevated site that is highly affected by transport, so Echo Summit alone was not sufficient to qualify a day for use.

A total of 90 days passed the initial screening with respect to (1) annual design values and (2) elevated ozone at Sandy Way. From the 90 days, all days on which the basinwide maximum exactly equaled the basinwide design value (for the associated year) were selected. A balanced number of days above and below the design value were then selected for a total of 18 days.

Mountain Counties. The Mountain Counties Air Basin (MCAB) includes 15 sites that measured ozone in the 1996 to 2004 period. Many of these sites are in the Sierra Foothills and can record the basinwide maximum ozone on one or more days each year. Therefore, at least four sites with relatively high ozone were required unless Cool (Highway 193) was the high site. In that case, only three sites were required.

A total of 128 days passed the initial screening with respect to (1) annual design values and (2) the minimum number of sites required. On five of the qualifying days, the basinwide ozone equaled the basinwide design value, and these days were selected. A balanced number of days above and below the design value were then selected to make a total of 18 days. On average, 5.1 sites per day recorded relatively high ozone on the 18 days selected for the MCAB.

Mojave Desert. The Mojave Desert (MD) Air Basin included a total of nine sites that measured ozone from 1996 to 2004. All of these sites are in desert areas east of the highly populated South Coast Air Basin (SoCAB, Los Angeles Metropolitan Area). Transport from the SoCAB usually contributes to high ozone levels measured in the MD, including those measured at the two key sites, Hesperia and Phelan.

A total of 134 days passed the initial screening with respect to (1) annual design values and (2) the minimum number of sites. Because seven of the nine sites recorded the daily maximum ozone on one or more of the days that passed initial screening criteria, days with less than three sites with relatively high ozone were excluded (unless the high site was Hesperia or Phelan). Days with two relatively high sites were included if the high site was Hesperia or Phelan. On five of the days that qualified, the basinwide daily maximum ozone was equal to the basinwide design value. A balanced number of days above and below the design value were then selected for a total of 18 days.

North Coast. The North Coast (NC) Air Basin stretches from the Oregon border to the northern portion of Sonoma County near the San Francisco Bay Area. Only three sites measured ozone in this basin from 1996 to 2004, with Healdsburg Airport in Sonoma County almost always the high site.

A total of 67 days passed the initial screening. Of these, seven days had basinwide maximum ozone equal to the basinwide design value (for the associated year). A balanced number of days above and below the design value were then selected for a total of 18 days.

North Central Coast. In the North Central Coast (NCC) Air Basin, ozone was measured at ten locations from 1996 to 2004. The Pinnacles National Monument and Hollister sites almost always recorded the daily basinwide maximum. If either of these sites was the high site, then one additional site with relatively high ozone was sufficient to qualify the day for selection. Otherwise, three or more sites with relatively high ozone were required.

A total of 41 days passed the initial screening. Of these, four days had basinwide maximum ozone equal to the basinwide design value (for the associated year). A balanced number of days above and below the design value were then selected for a total of 18 days. One of the selected days, 4/27/2004, was outside the May-October ozone season. Nevertheless, that day was selected because seven of the nine sites that measured ozone that day were all relatively high and because the highest ozone levels in the NCC often occur in the early spring and late fall rather than in the middle of the summer.

Northeast Plateau. In the Northeast Plateau (NEP) Air Basin, only one station, Yreka, measured ozone from 1996 to 2004. Ozone levels in the NEP are consistently very low, and Federal 8-hour design values were less than 70 ppb.

A total of 185 days passed the initial screening because of the generally low ozone levels in the NEP. Of these, 15 days had basinwide maximum ozone equal to the basinwide design value (for the associated year). Two more days above and one day below the design value were then selected for a total of 18 days.

South Coast. In the South Coast Air Basin (SoCAB), ozone was measured at 28 sites from 1996 to 2004. Crestline recorded the basinwide maximum ozone on 40% of the 92 days that passed the initial screening criteria. The second most common high site was Redlands (close to Crestline), which recorded the daily maximum on 27% of the screened days. No other site recorded the basinwide maximum on more than 7% of the screened days.

If Crestline was the high site, two additional sites with relatively high ozone were sufficient to qualify a day for selection. Otherwise, three additional sites were required. Of the 92 days that passed the initial screening, two had basinwide maximum ozone that equaled the basinwide design value (for the associated year). A balanced number of days above and below the design value were then selected for a total of 18 days.

South Central Coast. In the South Central Coast Air Basin (SCC), which includes Santa Barbara, San Luis Obispo, and Ventura Counties, ozone was measured at 33 sites between 1996 and 2004. The basinwide maximum was recorded at the Simi Valley site or the Ojai site on 49 of the 59 days (84%) that passed the initial screening. If either of these sites was the high site, a total of three sites with relatively high ozone was sufficient to qualify a day for selection. Otherwise, four sites with relatively high ozone were required.

On three of the 59 days that passed initial screening, the daily maximum ozone was equal to the design value (for the associated year). A balanced number of days above and below the design value were then selected for a total of 18 days.

San Diego. San Diego County (SD) is considered to be its own air basin. Between 1996 and 2004, 11 sites collected ozone data. Alpine was the high site in the SD basin on 20 of the 37 days (54%) that passed initial screening, and Escondido was the second most frequent high site. If either of these sites was the high site, only two sites with relatively high ozone were enough to qualify the day for selection. Otherwise, at least three sites were required.

Of the 37 days that passed initial screening, not one had daily maximum ozone exactly equal to the design value, so 9 values above the design value and 9 values below the design value were selected for a total of 18 days.

San Francisco Bay Area. The San Francisco Bay Area Air Basin (BAAB) includes seven entire counties and portions of two other counties. Between 1996 and 2004, 23 sites collected ozone data in the BAAB. On the 73 days that passed initial screening criteria, the most common high sites were Livermore (27%), San Martin (22%), Concord (15%), Bethel Island (12%), and Gilroy (10%).

Of the 73 days that passed initial screening, three had daily maximum ozone equal to the design value. A balanced number of days above and below the design value were then selected for a total of 18 days. On the 18 selected days, 5.4 sites on average measured relatively high ozone.

San Joaquin Valley. The San Joaquin Valley Air Basin (SJV) is an inland region that includes seven entire counties and a portion of another. Between 1996 and 2004, 26 sites collected ozone data in the SJV. High ozone levels can be widespread in the SJV due to geographical and climatic factors, which led to 289 days passing the initial screening criteria. On these days, the most common high sites were Arvin (31%), Fresno - Sierra Skypark #2 (18%), and Parlier (12%).

Additional conditions were used to eliminate some of the 289 days that passed initial screening. Days that involved fewer than 4 sites measuring relatively high ozone were excluded. If Sequoia (a mountain site far downwind of major sources) was the high site, at least five sites with relatively high ozone were required. Of the remaining days, nine had daily maximum ozone equal to the design value. Additional days were selected from those within 2 ppb of the design value (above or below) to make a total of 18 days. On the 18 selected days, 8.9 sites per day on average measured relatively high ozone.

Salton Sea. The Salton Sea Air Basin (SSAB) includes Imperial County and a central portion of Riverside County. Between 1996 and 2004, eight sites collected ozone data in the SSAB. Ozone levels at sites in the SSAB are often affected strongly by transport. Calexico sites are routinely affected by pollutants from Mexico, while the Palm Springs and Indio sites are regularly affected by pollutants from the SoCAB. For the 91 days that passed initial screening, Palm Springs was the high site 53% of the time.

If Palm Springs was the high site for a day, then one additional site measuring relatively high ozone was sufficient to qualify a day for selection. Otherwise, a total of three sites were required. Of the qualifying days, three had basinwide maximum ozone equal to the design value. Additional days above and below the design value were selected for a total of 18 days.

Sacramento Valley. The Sacramento Valley Air Basin (SVAB) is an inland region that includes nine entire counties and portions of two more counties. Between 1996 and 2004, 25 sites collected ozone data in the SVAB. On the 142 days that passed initial screening criteria, the most common high sites were Folsom (27%), Auburn (17%), Sloughhouse (15%), Redding (12%), and Sacramento – Del Paso Manor (10%).

Additional conditions eliminated three of the 142 days that would otherwise have qualified for the final selections. Two dates on which Redding recorded the basinwide maximum ozone were excluded because it is unusual for Redding to be the high site. However, another Redding date was retained because ten sites also recorded relatively high ozone concentrations on that day. A third day was eliminated when Rocklin was the high site and only two other sites recorded relatively high ozone levels. Of the remaining qualifying days, five had daily maximum ozone equal to the design value. Thirteen more days, some above and some below the design value, were then selected for a total of 18 days.

All of the selected dates included four or more sites with relatively high ozone, except one date included three sites with relatively high ozone when Auburn was the high site. On the 18 selected days, 5.8 sites per day on average measured relatively high ozone.

D. Summary and Coincidence of Day Selection

This section outlined the methods used to select the days for constructing new temperature and relative humidity profiles for EMFAC. For each air basin, three sets of days with high ozone levels have been selected. These three sets include days when the federal 8-hour, the state 8-hour, and the state 1-hour ozone standards are challenged.

Dates selected with respect to the federal 8-hour ozone standard matched the dates selected with respect to the state 1-hour ozone standard 45% of the time. Similarly, 50% of the dates selected for the federal 8-hour ozone standard were the same as those selected with respect to the state 8-hour standard. Also, the days selected with respect to the state 8-hour ozone standard matched those selected with respect to the state 1-hour ozone standard 60% of the time. Finally, all dates for the federal and state 1-hour ozone standard dates were the same; though the levels specified for these standards are quite different, their design values target the same percentile (the 364/365th percentile) of measured ozone concentrations.

Step 3:
Estimation of Sub-regional Hourly Temperature and Relative Humidity Profiles

A. Problem Description

There is a need to update the hourly temperature and relative humidity profiles to represent high ozone days in California's official mobile source emissions model, EMFAC. In EMFAC these are called "summer" profiles. This document describes how hourly county-specific diurnal temperature and relative humidity profiles were developed for this purpose, using data from days selected in Step 2.

The Need for Improved Profiles. Following the selection of appropriate days, staff identified two areas of improvement needed for the methods used to generate the existing summer profiles for the current version of EMFAC. The first area of improvement concerns the sources of meteorological data that were used to generate the profiles. In particular, the California Irrigation Management Information System (CIMIS) data that were previously used may not be representative of county-wide temperature and relative humidity averages. This is because CIMIS stations are often located at non-standard measurement platform heights and in irrigated areas. Temperatures in an irrigated area may be several degrees lower than near roadways in summer months.

Another area of improvement concerns the prior use of vehicle registration zip code boundaries as the spatial basis for calculating county-average profiles. This is problematic for two reasons: (1) the zip code of vehicle registration does not necessarily reflect where vehicles emit; and (2) large spatial temperature gradients can occur over a zip code area, particularly in rural areas. A better characterization of the temperature and relative humidity where the emissions actually occur is needed. For this project staff used gridded vehicle miles traveled (VMT) as the basis for calculation of weighted averages of gridded, county-wide model estimates of temperature and relative humidity. The grid resolution is 4 km by 4 km.

B. Methodology

Because monitoring data only provide a sparse representation of temperature and relative humidity, a method was necessary to interpolate temperature and relative humidity from scattered observation data points to a grid defined on a statewide domain. Fundamentally, two types of meteorological models can be used to generate a statewide gridded temperature field. One type is a prognostic meteorological model (e.g. MM5), and the other is a diagnostic meteorological model (e.g. CALMET). The computational resources required for the prognostic model are generally much greater than the diagnostic model. For the purpose of generating ground-based temperature and relative humidity fields, the prognostic method is not superior to the diagnostic method where sufficient measurements are available. Staff elected to use the CALMET diagnostic meteorological model (Scire et al., 2000) to interpolate observed temperatures spatially and temporally to obtain temperatures on a 4 km by 4 km grid. CALMET has been widely used in various applications including providing input to regional air quality models (e.g., CALGRID) and dispersion models (e.g., CALPUFF).

Since the current version of CALMET does not generate estimates of relative humidity, staff ran a separate program that uses the same method of temperature interpolation employed by CALMET to calculate relative humidity on a grid covering the whole state. This method is discussed in more detail later.

The gridded, hourly temperature and relative humidity fields must be averaged over each county portion of air basin for input to EMFAC. The approach used for this task was to average gridded estimates of temperature and relative humidity using gridded VMT as a weighting factor. The reason for this is to favor gridded temperatures where on-road emissions actually occur. This is in contrast to a simple average where all gridded temperatures in a region are considered equally, or the zip code-based scheme used in EMFAC2000, where the registered owner's zip code boundary was considered to be where the emissions occur.

The VMT-weighted average considers each grid cell temperature or relative humidity value in proportion to the VMT in each grid cell. Thus, use of CALMET coupled with VMT weighting is intended to result in more refined estimates of meteorological conditions near the roadways in each region.

***Summary of Approach*.** Staff reformatted observed temperature data (described in more detail below) for use in CALMET using a preprocessing program specifically written for this study (See Appendix B-1). CALMET was then used to compute a domain-wide gridded temperature field based on the observed data. The principal steps involved in generating a gridded, surface-level temperature field include the following:

(1) Compute the relative weights of each surface observation station to each grid cell in question (the weight is inversely proportional to the distance between surface observation station and grid cell center).

(2) Adjust all surface temperatures to sea level. In this step, a lapse rate of -0.0049 ^{o}C/m was used (this lapse rate is based on private communication with Gary Moore of Earth Tech, Inc., Concord, MA). This lapse rate (=2.7 F/1000 feet) is close to what was used in previous EMFAC calculations [3]

[3] Section 7.8 of EMFAC2000 documentation can be found at http://www.arb.ca.gov/msei/on-road/downloads/tsd/Temperature_Profiles.pdf

(2.4 F/1000 feet). The current and previous lapse rates are based on observational data.

(3) Use the weights to compute a spatially-averaged sea-level temperature in each grid cell.

(4) Correct all sea-level temperatures back to 10 m height above ground level (i.e. the standard height of surface temperature measurement) using the lapse rate of -0.0049 ^oC/m again.

A statewide domain consisting of 273 x 273 grid cells, each measuring 4 km x 4 km, was used in the CALMET modeling. The grid system is based on a Lambert Conformal conic map projection with the following specifications: 1st and 2nd standard parallels are 30 degrees and 60 degrees, respectively; the central meridian is 120.50 degrees, and the latitude of projection origin is 37 degrees. Details about model setup and selection of model parameters are shown in Appendix B-2. Figure 3-1 shows the modeling domain. Terrain elevation features are also shown in the figure.

The current version of CALMET does not generate estimates of relative humidity. As a result, a post-processing program was used to produce gridded, hourly relative humidity estimates from observed relative humidity data. The post-processing program, summarized below, is included in Appendix B-3.

(1) Calculate actual vapor pressure from observed relative humidity and temperature at all meteorological stations. The McRae (1980) method was used to calculate the saturated vapor pressure from temperature;

(2) Compute the relative weights of each surface observation station to each grid in question, exactly as done by CALMET to compute the temperature field;

(3) Use the weights from step 2 to compute a spatially-averaged estimate of actual vapor pressure in each grid cell;

(4) For each grid cell, calculate relative humidity from values for actual vapor pressure and temperature for the same grid cell.

Finally, gridded, hourly temperature and relative humidity estimates were subjected to a VMT-based weighting scheme to yield a single hourly estimate for each county portion of air basin as follows (Appendix B-4):

(1) For each county portion of each air basin subarea, normalize hourly, gridded VMT into gridded VMT ratios (such that a summation of gridded VMT ratios for each hour in each region yields a value of 1.0).

(2) Calculate an hourly, weighted average of temperature and relative humidity for each region using the gridded, hourly VMT ratios from the step above and gridded, hourly temperatures and relative humidities.

The programs used for these steps are included in the Appendices.

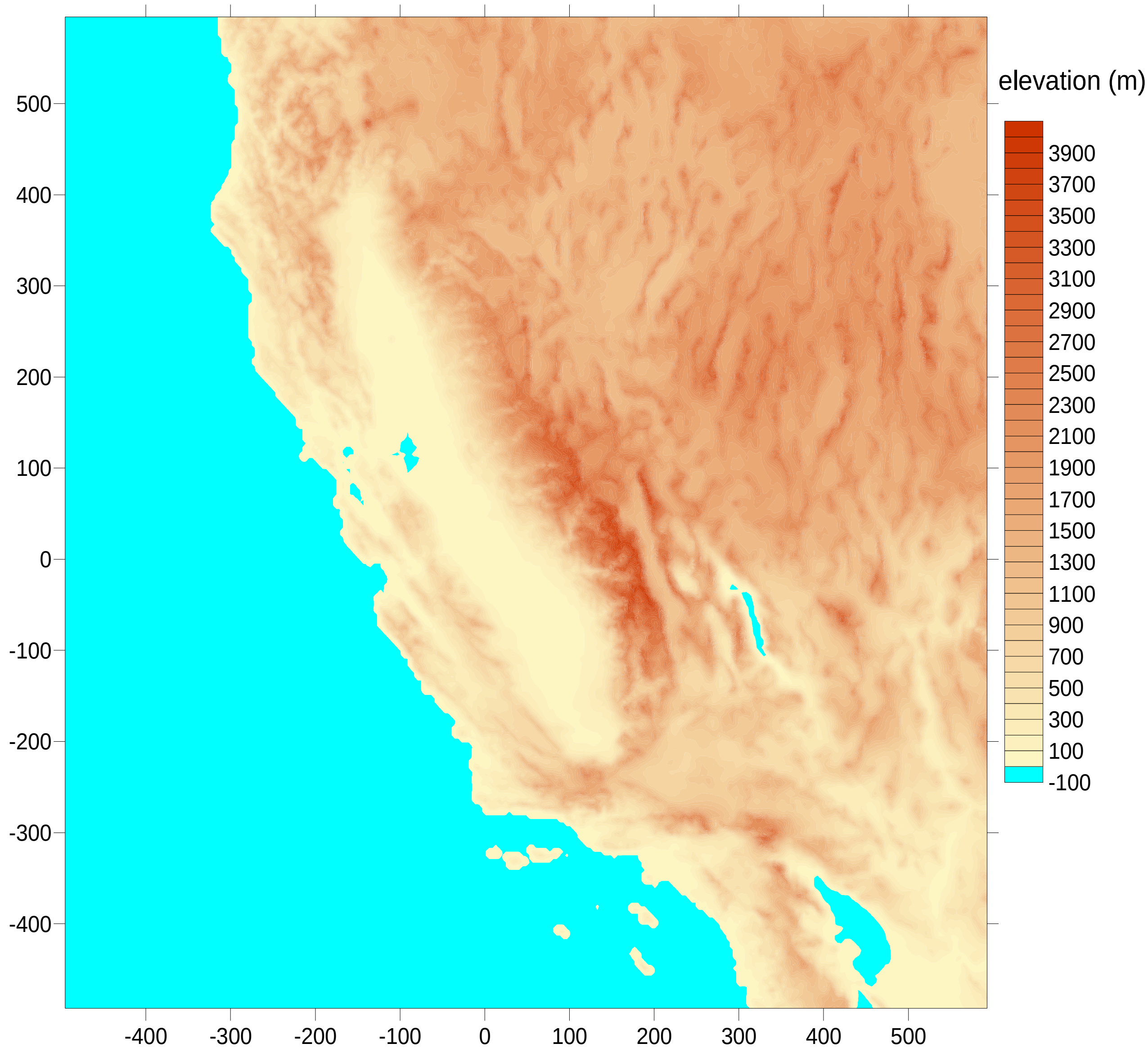

Figure 3-1. CALMET Modeling Domain.

C. Input Data and Quality Assurance

This section describes the observed meteorological data, vehicle miles traveled (VMT) data, and quality assurance steps that staff utilized.

Temperature Data. Three sources of observed meteorological data were used: the Aerometric Information Retrieval System (AIRS), the National Climatic Data Center (NCDC), and the Remote Automated Weather Stations (RAWS). These sources each collect meteorological data on platforms 10 meters above ground level. Upper air sounding data were not required. Table 3-1 shows the number of stations for each of these three sources. As a gross quality assurance step, the gridded VMT was plotted (Figure 3-3) with county and air basin boundaries and roadways to verify the location of the gridded data.

Table 3-1. Surface Meteorological Data Sources

Data Source	Number of Stations	Web Links
AIRS	238	http://www.epa.gov/air/data/index.html
NCDC	101	http://www.ncdc.noaa.gov/oa/ncdc.html
RAWS	351	http://www.wrcc.dri.edu/index.html

The following quality assurance and control (QA/QC) steps were taken to identify questionable data. All associated questionable data were flagged and not used in the subsequent procedures.

- Checks performed on these data included range checks (data outside of a given range were marked as bad) and continuity checks (data that deviated by more than a fixed amount from neighboring data points were marked as bad).

- Plots of the meteorological station coordinates against political boundaries were used to check the locations of stations for gross errors (Figure 3-2).

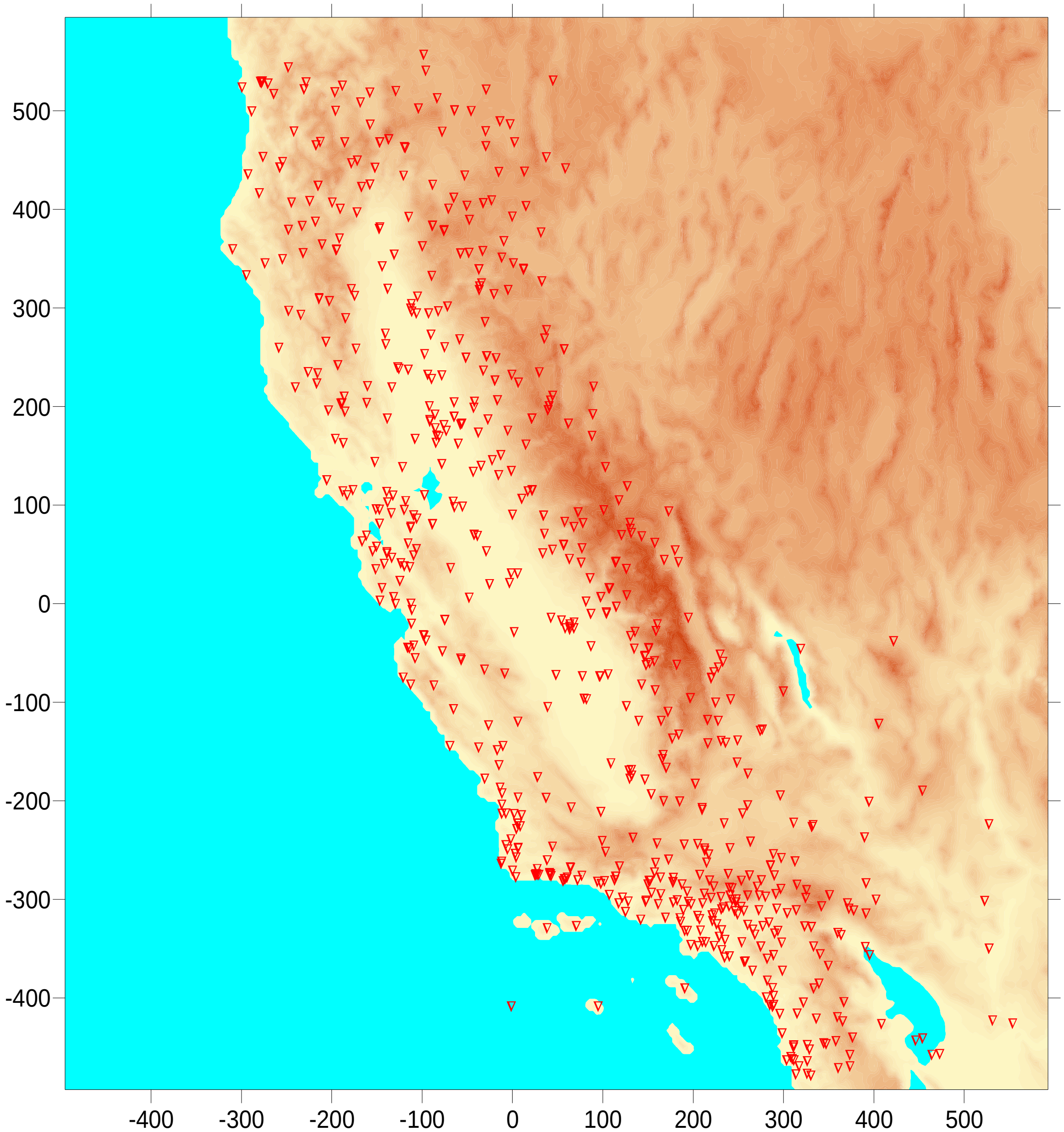

Figure 3-2. Locations of Surface Meteorological Stations

Vehicle Miles Traveled (VMT) Data. Gridded, hourly vehicle miles traveled (VMT) data were used to weight gridded temperature and relative humidity estimates obtained from the CALMET model. More specifically, link-based, hourly VMT data from the California Integrated Transportation Network (ITN) was used to create the gridded VMT. The ITN was developed for the Central California Ozone Study (CCOS) by Alpine Geophysics (Wilkinson, 2005). Staff created and reviewed the hourly plots of gridded VMT as a gross QA check of hourly VMT (Figure 3-3).

Figure 3-3. Gridded VMT, Roadways, and Boundaries

The Riverside County/Mojave Desert region is the only region for which obvious data deficiencies were evident (i.e. in this case, there is not sufficient VMT coverage in the ITN). The following plot illustrates this. For this reason the simple average temperature and relative humidity were used for this region.

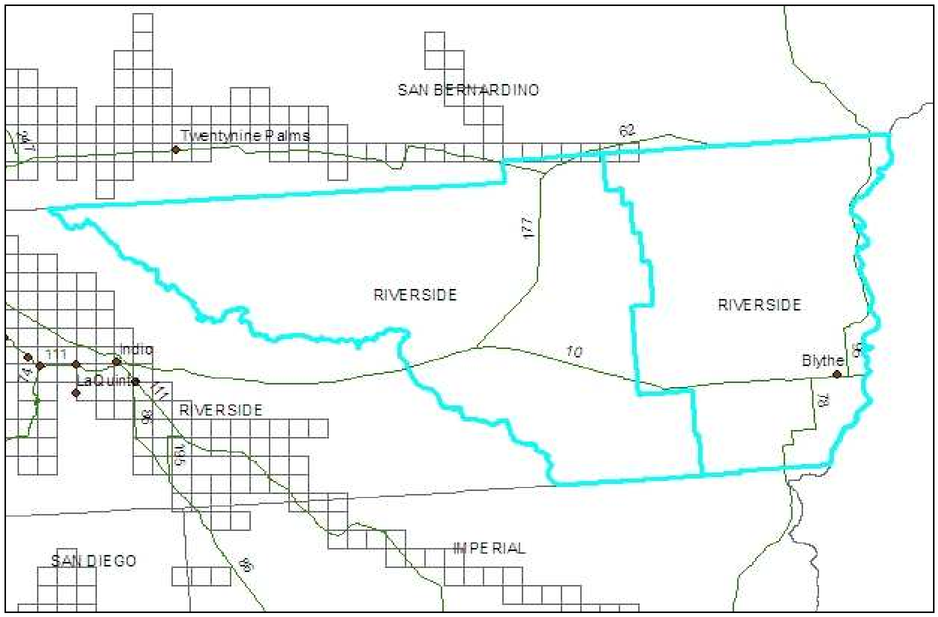

Figure 3-4. Gridded VMT, Roadways, and Boundaries in Riverside County /Mojave Desert

D. Results - Diurnal Temperature and Relative Humidity Profiles

Results are summarized as a series of plots in Appendix B-5. Each page contains three temperature or relative humidity profile plots for one county portion of an air basin. The three plots differ according to the data that were used to generate them. More specifically, each plot includes profiles based on approximately eighteen days of data between 1996 and 2004 that represent basin-specific design-day conditions for an ozone standard(s):

(1) Federal 8-hour;
(2) State 8-hour; or
(3) Federal or State 1-hour.

Each of the three plots also contains three lines, defined as follows:

(1) EMFAC - A solid line that represents the existing hourly temperatures (^{o}F) or relative humidities (%) contained in the current version of EMFAC;

(2) VMT Wt - A large-dashed line that represents a VMT-weighted-average temperature or relative humidity profile for a county-basin region (based on data that represent design-day conditions for the denoted standard in the basin); and

(3) Simple Average - A small dashed line that represents the simple average of the temperature or relative humidity data (i.e. non-VMT weighted) for each county-basin region for the same set of days as above.

In addition, each plot contains a scatter plot of each of the roughly 18 VMT-weighted daily profiles that were averaged to generate the VMT-weighted temperature or relative humidity profile. Data points marked with a "+" are those that were collected during typical summer months (specifically, June 15th through September 15th) while data points marked with an "O" were collected outside of typical summer months.

Quality Assurance Review. A thorough quality assurance review of the VMT-weighted temperature and relative humidity results was conducted. All new temperature and relative humidity profiles were examined, and those that were markedly different from the prior profiles, as well those showing major differences for simple and VMT weighted averages, were identified and investigated. We concluded that these major differences occurred in the following circumstances:

- In sparsely populated counties, the zip-code averaging scheme used to calculate the current profiles and the new VMT-weighted scheme can lead to major differences. Tehama County is shown as an example in Appendix B-6,;

- When major temperature gradients exist, the simple average and zip-code average method can be problematic (Placer County is an example);

- CIMIS data used previously tend to underestimate temperatures since they are collected near agriculture areas and water sources;

- Relative humidity in the new profiles is generally lower than the values in the current profiles. The lower humidities are consistent with the differences in temperatures, since the same amount of water vapor at a higher temperature means a lower relative humidity.

Detailed QA/QC results for specific regions are provided in Appendix B-6.

In conclusion, the new diurnal profiles of temperature and relative humidity are improvements to the current EMFAC profiles. Improvements include (1) the selection of days that address specific ozone standards, (2) the VMT weighting scheme that replaces the previous zip code-based averaging method, and (3) omitting data from sources that are not as representative of the conditions experienced by on-road vehicles.

APPENDICES for Step 3

Appendix B-1	Preprocessing Code
Appendix B-2	CALMET Control File (Including Model Setup)
Appendix B-3	Post-processing Code: Statewide Temperature and Relative Humidity
Appendix B-4	Post-processing Code: Calculating County Averages of Temperature and Relative Humidity
Appendix B-5	Results - Diurnal Variations of County Specific Temperatures and Relative Humidity
Appendix B-6	QA/QC of Results - Counties or Dates Where Big Difference Occur with Different Averaging Schemes

Step 4

Effects of Revised EMFAC Temperature and Relative Humidity Profiles on Emissions Estimates

The temperature and humidity of the ambient air affect the emissions of pollutants from on-road vehicles. The ambient temperature directly affects the evaporation rates of reactive organic gases (ROG). Temperature and humidity together affect the use of air conditioning, which increases engine load and the emissions of ROG, carbon monoxide (CO), and nitrogen oxides (NOx). Also, the temperature and humidity can affect combustion characteristics inside engines, which may alter the emissions of ROG, CO, and NOx. Therefore, diurnal profiles for ambient temperature and relative humidity are used in the EMFAC model to improve the accuracy of emissions estimates under different temperature and humidity conditions.

The current EMFAC model includes profiles for temperature and relative humidity that characterize the ambient conditions for each county in California.[4] Separate profiles are included to represent average conditions for each month of the year. From the monthly profiles, an annual profile is constructed as needed. In addition, EMFAC contains two seasonal profiles, one for the "summer" and one for the "winter."

The two seasonal profiles in EMFAC represent conditions that promote high ozone levels in the summer and high CO levels in the winter. Although other factors affect ozone levels, temperatures are usually higher and relative humidities are usually lower than average on days when ozone concentrations are high. The profiles produced during this project represent the temperatures and humidities characteristic of "design day" conditions with respect to various ozone standards. For the Federal 8-hour ozone standard, design day conditions are those associated (on average) with the 4th highest concentration measured in a year.[5]

The new temperature and relative humidity profiles will be stored in data arrays by "geographic area index" (GAI), corresponding to county portions of air basins. The data arrays are part of the FORTRAN source code for EMFAC. Together with the monthly, annual,[6] and winter temperature profiles, the new temperature profiles will replace the "summer" profiles that are hardcoded in the file *TempAssign.for* (in the subroutine TEMP_INIT of the TEMP_DATA module). The new profiles for relative humidity will replace the summer profiles that are

[4] The data arrays in EMFAC allow for different profiles for portions of a county that are in different air basins, but the current contents of these arrays are the same for all portions of a county.

[5] The "design value" for the Federal 8-hour ozone standard is the average of three 8-hour ozone values, where each value is the 4th highest daily maximum value within a year.

[6] The EMFAC data arrays have places for annual profiles, but the values stored there are constant, and annual profiles are calculated at runtime from the monthly average profiles.

hardcoded in the file *RHAssign.for* (in the subroutine RH_INIT in the RH_DATA module).

In general, the new hourly temperatures representing design day conditions for the federal 8-hour ozone standard are higher than the previous temperatures by 5 to15 degrees Fahrenheit. Hourly relative humidities, on the other hand, are lower by 5 to 15 percent.

An evaluation version of the EMFAC model was executed with the new temperature and relative humidity profiles for calendar years 2002 and 2020. Table 4-1 provides changes in emissions when the current temperature and relative humidity profiles are simultaneously replaced with the new profiles.

Table 4-1. Changes in Emissions Resulting from Application of Revised (Federal 8-Hour Ozone Standard) Temperature and Relative Humidity Profiles in EMFAC Version 2.22.8, Tons per Day (%)

2002			
Area	ROG-All processes	CO-All processes	NOx-All processes
Statewide	59.22 (5.16%)	302.55 (2.94%)	37.69 (2.95%)
South Coast AB	6.89 (1.55%)	35.40 (0.92%)	15.43 (2.68%)
San Joaquin AB	9.66 (7.62%)	67.45 (6.04%)	12.02 (4.04%)
Sacramento AB	7.61 (7.47%)	54.79 (5.86%)	4.58 (2.74%)
San Diego AB	1.24 (1.41%)	5.01 (0.61%)	4.35 (3.50%)
San Francisco AB	15.29 (6.96%)	91.85 (4.50%)	4.10 (1.40%)
2020			
Area	ROG- All processes	CO-All processes	NOx- All processes
Statewide	31.91 (7.44%)	79.77 (2.90%)	11.24 (1.80%)
South Coast AB	3.50 (2.30%)	8.26 (0.90%)	4.20 (2.28%)
San Joaquin AB	5.43 (10.29%)	17.23 (5.37%)	3.44 (3.21%)
Sacramento AB	4.46 (10.60%)	14.66 (5.43%)	1.32 (2.32%)
San Diego AB	0.92 (2.53%)	1.18 (0.97%)	1.39 (3.00%)
San Francisco AB	7.99 (10.99%)	20.21 (4.05%)	1.07 (1.24%)

Conclusion and Implications

ARB staff produced new hourly temperature and relative humidity profiles for each county portion of each air basin in California. The new profiles represent regional conditions that challenge the attainment and maintenance air quality standards for ozone. Separate sets of profiles were developed for use with respect to the federal 8-hour, the state 8-hour, and the state (and federal) 1-hour ozone standards. The regional diurnal temperature and relative humidity profiles representing the federal 8-hour ozone standard are proposed to be integrated into the EMFAC model, replacing the “summer” profiles currently installed in the model. The profiles that address other standards are only documented at this time.

Hourly temperature and relative humidity data measured at monitoring stations for nine years, 1996 through 2004, were used to construct the new profiles. For each air basin, profiles were based on temperature and relative humidity data measured on days when the basinwide maximum ozone was close to the basinwide design value. For this purpose, about 18 days were selected (two days per year on average) with respect to each standard for each air basin. The temperature and relative humidity data were analyzed with a diagnostic meteorological model to estimate temperatures and relative humidities in each cell of a 4 km × 4 km statewide grid.

The new profiles were created using a weighted average of the gridded temperature and relative humidity data. Hourly gridded vehicle miles of travel (VMT) from the Integrated Transportation Network model (ITN v.2) were used as weights in the weighted averages. The profiles were constructed in this manner so they would represent the conditions that on-road vehicles experience during the course of a high-ozone day.

The new profiles contain higher temperatures and lower relative humidities compared to the “summer” profiles currently installed in the EMFAC model. The largest absolute differences are found during nighttime hours, when typically the temperatures are lowest and relative humidities are highest compared to the other hours of the day.

Changes in Estimated Emissions. Compared to the “summer” profiles currently installed in EMFAC, the new profiles lead to statewide increases in the emissions estimates for ROG, CO, and NOx. For 2002, statewide estimates increase by 5.16% for ROG, 2.94% for CO, and 2.95% for NOx. For 2020, the estimates increase by 7.44% for ROG, 2.90% for CO, and 1.80% for NOx. Among the five most populous air basins in 2002, increases in ROG range from 1.55% in South Coast to 7.62% in the San Joaquin Valley, while increases in NOx range from 1.40% in the Bay Area to 4.04% in the San Joaquin Valley. Percentage differences are highest for ROG and lowest for NOx in 2020.

Planning Implications. Better representation of the days that challenge attainment and maintenance of the 8-hour ozone standard, the use of more recent data, and utilization of methods to reflect temperatures and relative humidities where on-road travel occurs will enable staff to estimate on-road planning inventories and emissions budgets in SIPs more accurately. Moreover, the new profiles will enable a better understanding of the effectiveness of our plans and programs for complying with the federal 8-hour ozone standard. The differences in estimated emissions resulting from use of the new profiles are not significant enough to reconsider current control strategies targeting emissions reductions from on-road vehicular travel. Overall effects on emissions and emission trends, however, re-emphasize the need for ROG reductions.

REFERENCES

California Air Resources Board (2000). On-Road Emission Model Methodology Documentation, Section 7.8 County-Specific Diurnal Temperature Profiles (http://www.arb.ca.gov/msei/on-road/doctable_test.htm).

McRae, G.J. (1980). “A Simple Procedure for Calculating Atmospheric Water Vapor Concentration.” J. Air Pollution Control Assoc. 30, 394-396.

Scire, J.C. et al. (2000). “A User’s Guide for the CALMET Meteorological Model (Version 5).” Earth Tech, Inc., Concord, MA.

Wilkinson, J. G. (2005). “Development of Version Two of the California Integrated Transportation Network (ITN).” Final report prepared for Vernon Hughes, Manager, Control Strategy Modeling Section, CalEPA- Air Resources Board, Planning and Technical Support Division, 1001 I Street, Sacramento, CA. Prepared by Alpine Geophysics, LLC, Report Reference # AG-TS-90/155.